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Its Opportunities and Obstacles

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CHEMICAL UTILIZATION OF WOOD: ITS OPPORTUNITIES AND OBSTACLES[1]

By

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Wood Waste

It is hardly necessary to point out to foresters the huge amount of wood that is wasted each year in the United States. Even Mr. Average Citizen is becoming mindful of the vast waste. The Forest Products Laboratory receives letters regularly from those who are anxious to do something constructive in utilizing wood waste but who need help in doing so. This situation has been brought to the attention of Congress. As a result, they have earmarked a small increase in the Forest Products Laboratory appropriation for this fiscal year to be used in studying the chemical utilization of wood. It is hoped that this amount will be further increased in future years as the chemical approach to this important problem shows much promise of making important contribution to the eventual solution of the waste problem on an economic basis.

Although the Laboratory's approach to the problem is from the chemical standpoint, it will take more than the chemist to solve it adequately. Even if the chemist had all the chemical facts regarding a potential utilization process, there is still the necessity of determining its economic and mechanical feasibility. Economical harvesting and transporting of wood waste so that it can be delivered cheaply for chemical use seems to be the biggest obstacle confronting the chemical utilization of wood. This phase of the over-all problem is the one in which foresters and engineers can make their biggest contribution. Those who are anxious to contribute to the solution of the waste-utilization problem can well focus attention on harvesting and transportation of woods waste in small log, cordwood, chip, or sawdust form.

Chemical Utilization

The chemical utilization of wood may be divided into several types of processes: (1) pulping, (2) extraction, (3) hydrolysis (converting

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carbohydrates to sugars), (4) destructive distillation, (5) reactions with various chemicals such as hydrogen and chlorine, and (6) chemical treatments to improve the properties of wood and make possible the utilization of inferior species for structural use.

Pulping

Pulping processes are the oldest and best known of the processes for chemical utilization of wood. Experience has shown, however, that pulping cannot be done profitably on a small scale. Large-scale and costly equipment is necessary for efficient and economical operation.

Attempts have been made to operate pulp mills on inferior quality wood and waste. In a few instances these attempts have been successful. A notable example is the pulping of chestnut chips that have been extracted for tannin. In general, operators who have tried using low-grade wood have abandoned its use and turned to high-quality material in order to increase the returns from their investments. As quality material becomes less available, these operators can and will return to the use of the less desirable woods.

Development of a simple means of barking hardwoods at all seasons as well as small crooked softwood logs will help materially in getting the pulp mills to use more of the presently unpopular species and lower-grade woods. Softwood mill waste is now being utilized by some pulp mills operating in conjunction with a sawmill. All logs going to the mill are prebarked. The slabs and, for some forms of paper, even the sawdust are being used for pulping.

Work at the Forest Products Laboratory on diversification of pulping species, notably the pulping of southern resinous softwoods and the semichemical pulping of hardwoods, has gone a long way toward making all available species suitable for pulping. The inclusion of some hardwoods in southern pine pulping operations has been shown to be practical and highly advantageous from a silvicultural and economic standpoint. Foresters can aid in getting various mill operators to follow such practice.

Efforts are being made to utilize more completely pulp-mill waste liquors. These liquors contain soluble lignin, hemicelluloses, and wood extractives which have considerable potential chemical value. In the sulfate pulping of Southern yellow pine, turpentine and tall oil are now being recovered to a limited extent. Yield of tall oil as high as 200 pounds per ton of pulp are obtained. The tall oil is finding use in drying oils and soaps. Further purification and fractionation should increase its value and uses.

Sulfite waste liquor is being used to some extent as a dust settler for roads. Lignin is finding use as a dispersing agent for cement in the making of concrete; it is being incorporated in the negative plate paste of electrical storage batteries; and it is used in making vanillin, the active constituent in vanilla extract.

Cooperative research between the Forest Products Laboratory and a Canadian mill has demonstrated the possibility of using soda-mill lignin in laminated plastics. Soda-mill lignin is the simplest to isolate and has the best plastic properties of the various forms of lignin waste. It can be incorporated with the pulp in a beater to form a laminating sheet which requires no auxiliary resin to produce a dense plastic material with good properties. The Forest Products Laboratory has also shown that soda-mill lignin can be used as a phenolic-resin diluent. The lignin is dissolved in a laminating resin solution and can be applied to paper or fabric. It can replace 50 percent of the phenolic-resin ordinarily used without significantly affecting the properties of the resulting laminate.

The hemicellulose portion of pulping-waste liquor has received less attention than the lignin even though it is present in the liquor in at least equal amount. The hemicelluloses are converted almost entirely to sugars in the sulfite process. In the soda process they are much less degraded and can be isolated as starchlike products.

The sugars from the sulfite process are, to some extent, being fermented to ethyl alcohol and used for growing yeast, as will be described later. Ethyl alcohol is produced only from the hexose sugars and not from the pentose sugars. The pentose sugars can, however, be used for growing of yeast or fermenting to other products.

The chemistry and possible uses of hemicelluloses are being studied by the Forest Products Laboratory, where it has been shown that hemicelluloses can be isolated from wood in a practically undegraded form by a new potential pulping process. Practically all the carbohydrate constituents of wood (holocellulose) are isolated as a single solid fraction by subjecting wood chips to a semichemical pulping, followed by chlorination and mild alkali extraction. Various hemicellulose fractions can be extracted from the holocellulose by progressively stronger solvents, leaving a residual pulp that is considerably higher in alpha cellulose (high-molecular-weight undegraded cellulose) than normal pulps, and which shows promise of finding use in cellulose derivatives. Such a pulping method would not only give extra high yields of high-quality pulp, but would also make possible the isolation of valuable hemicellulose byproducts.

Extraction

Extraction processes can be profitably applied to only a relatively few species, such as the turpentine and rosin extraction of southern pine stumps and tannin extraction of chestnut and hemlock. These processes utilize only a small portion of the wood. The problem of utilizing the rest of the wood profitably still exists. This has in some instances been accomplished by pulping the extracted chips. For this use the wood should be barked prior to chipping and extraction. Extraction of wood for chemicals on a scale too small to use the spent chips for pulping may eventually become profitable if other means of utilizing the residual wood substance are found. Expanding the wood extraction industries thus depends to a large extent upon finding uses for the extracted chips.

Hydrolysis for Production of Alcohol

Next to pulping, wood hydrolysis has received major attention as a chemical utilization process at the Forest Products Laboratory during the last few years. Ethyl alcohol (grain alcohol) can be made from wood waste by hydrolyzing the carbohydrate portion of the wood to sugar, followed by fermentation of the sugar to alcohol. The general principles of this conversion have been known for years. At the time of World War I and shortly thereafter a process known as the American process using Southern yellow pine woods waste, was in operation in two plants in the United States; one at Georgetown, South Carolina, and the other at Fullerton, Louisiana. The process, which consisted of a single rapid digestion of the wood with dilute acid followed by extraction of the sugar and batch fermentation of the sugar liquors, produced about 26 gallons of 95 percent alcohol per ton of dry wood. Each plant produced about 2,500 gallons per day. Operation of these plants was finally discontinued because of the lack of adequate woods waste near the plants and the substantial lowering of the price of blackstrap molasses (to 5 cents a gallon) from which alcohol could be produced more cheaply.

About 1928 a multiple-cycle dilute-acid-hydrolysis process, known as the Scholler process, was developed in Germany. Yields of about 45 gallons per ton were obtained from hardwoods and 53 gallons per ton from softwoods. Cooking times, however, ranged from 16 to 20 hours. During World War II pilot-plant studies were intensively undertaken by the Forest Products Laboratory, first to duplicate and then to improve on the German process. This work has resulted in what is called the Madison wood-sugar process. Cooking liquor is continuously pumped through a bed of wood waste for 2-1/2 to 3 hours under properly controlled conditions, followed by a continuous fermentation. Yields of 55 to 65 gallons per ton of bark-free softwood waste have been obtained. The improved yield, together with the reduction in cooking time to as low as one-sixth to one-eighth of that for the Scholler process, gives the process a better commercial outlook. A Government-sponsored plant designed to produce 5 to 6 million gallons of alcohol a year from about 380 tons of sawmill wood waste per day by this method is under construction at Springfield, Oregon.

According to the Forest Products Laboratory experiments, wood with bark contents as high as 50 percent can be handled but with a significant drop in yield. Hardwoods can be used instead of softwood. Although the alcohol yield drops to about 45 gallons per ton, larger amounts of valuable byproduct wood alcohol and furfural can be recovered to offset the loss in ethyl alcohol yield. The Laboratory has also shown that yeast can be grown on the still bottoms, after recovery of the alcohol, to produce about 200 pounds of fodder-yeast byproduct per ton of dry wood.

From each ton of wood processed there is about 650 pounds of residual lignin. As yet there has not been found a profitable use for this residue. Present plans are to use it as a fuel in the plant boilers. This lignin is in a highly insoluble form and is not suitable according to present information for use in plastics in the same way that lignin residue from soda pulp

can be used. Work is under way at the Laboratory in the search for profitable uses for this residue.

This new alcohol process has created a great deal of public interest. In fact, almost everyone with a little sawdust pile wants to make alcohol. It is thus important to look at some of the economic aspects of the problem.

Consider wood waste in a hogged form delivered at the chemical plant to be worth $2.00 per ton on a dry-weight, bark-free basis. Moisture and some bark are acceptable but a processor will not pay for them. The wood cost per gallon of 95 percent alcohol would then be about 4 cents and the chemical cost would be about 6 cents. On the basis of a plant processing 60 tons of dry, bark-free waste per day (approximately 200 tons with bark and moisture), labor would cost about 8 cents per gallon of alcohol and plant investment and upkeep 16 cents a gallon. The production cost of alcohol would thus be 34 cents per gallon, a figure within reason. In a larger plant labor charges may be as low as 5 cents per gallon. On the basis of a 10-ton-a-day plant the total labor required would be almost the same as for a 60-ton plant, which, on the smaller daily output, would amount to perhaps 45 cents per gallon. A 10-ton-a-day plant might cost two-thirds as much to build as a 60-ton-a-day plant, bringing the plant investment and upkeep cost to 64 cents per gallon of alcohol. The production cost of alcohol from the 10-ton plant would thus be 1.19 per gallon. It is evident from these figures that the manufacture of alcohol from wood is necessarily a large-scale operation.

There is the possibility of hauling wood waste from several mills to a central chemical plant. By present handling methods it appears that wood waste cannot be profitably hauled much more than about 10 miles. There is the radius of haul tentatively chosen as economical for the Springfield wood-sugar plant.

Comparative cost of alcohol produced by other methods has a direct bearing on the commercial application of the process. Alcohol is being produced in the State of Washington and in Canada from sulfite-pulp waste liquor. Plant costs are about the same as estimated for the Madison wood-sugar process. No hydrolysis step is involved but, because of the more dilute liquor, larger volumes have to be handled. Production costs on a large-plant basis would probably be about 25 cents per gallon, which is somewhat less than the estimated cost of production by the Madison wood-sugar process. Alcohol was produced from blackstrap molasses at about 20 cents per gallon when the cost of molasses was 5 cents per gallon at the plant. At the present molasses price of 18 to 20 cents per gallon, it would cost 50 to 56 cents a gallon to produce alcohol from this source. Ethyl alcohol made from grain, at present grain prices, ranges in production cost from 85 cents to $1.50 per gallon, depending on the size and efficiency of the plant. Ethyl alcohol can be produced from petroleum at a somewhat lower cost than by the Madison wood-sugar process. It is hard to say, however, whether the petroleum companies will turn to making alcohol as long as they can make more profitable products. It thus appears that the future of making ethyl alcohol from wood waste depends upon the cost of blackstrap molasses not falling below 10 cents per gallon and the petroleum industry

not going into the manufacture of alcohol. Finding a profitable use for the residual lignin will also materially help the production of ethyl alcohol from wood. If all the sulfite liquor from pulp mills were fermented alcohol production from this source would be about 30 million gallons of alcohol per year, which is about 3 percent of present annual production. Some mills are too small to produce alcohol economically.

Other Fermentation Products

When wood sugars are fermented with the use of cultures and nutrients other than those used in producing ethyl alcohol, such products as acetone, butanol, 2,3-butylene glycol, and lactic acid can be produced. These find use as solvents and as raw materials for making synthetic rubber and plastics. As yet, available data on these processes are insufficient to indicate how they should be carried out commercially and what the cost of production will be.

Fodder yeast can also be grown on the total sugars as well as on the still bottoms. The extent to which this vitamin-containing food can be used profitably for feeding is still unknown. Cattle can assimilate urea, the nutrient ordinarily used in growing fodder yeast, and convert it into protein. It still remains to be proven whether fodder yeast is a better food for cattle than urea and to what extent it may replace other natural protein-containing foods. The quantity of fodder yeast made in this country up to the present time has been insufficient to make adequate feeding tests. This situation, however, should change soon.

Hydrolysis for Production of Plastics and Board Materials

Pioneer experiments by the Forest Products Laboratory showed that lignin, in a sense Nature's cementing material between the cellulose fibers, can be freed from the cellulose by a mild acid hydrolysis and be subsequently used as a semiplastic to bond the structure together again. Besides breaking the cellulose-lignin bond, the mild hydrolysis converts the hemicelluloses to sugars, while the stable cellulose remains with the lignin to serve as a plastic reinforcing material. The removed sugars can be either fermented or used for the growing of yeast. The residue is dried and then ground to a powder. Although this hydrolyzed residue does have some plastic properties, it does not make a good plastic when used alone, due to the extremely high temperature necessary to cause the lignin to flow even moderately and the relatively low water resistance of the product. For this reason it is preferably used in conjunction with other plastics such as phenol formaldehyde, which improves both the flow and the water resistance. Under these conditions a plastic quite similar in appearance, water resistance, and electrical properties to common black phenol-formaldehyde plastics can be made using 75 percent of hydrolyzed wood and 25 percent of phenolic resin. This can be contrasted with the 50 percent of wood flour and 50 percent of phenolic resin used in making the ordinary phenol-formaldehyde

molded products. The strength properties, notably toughness, are slightly lower than for the normal phenol-formaldehyde molded products, mold flow is also inferior, but acid-resistance properties are better.

A commercially developed modification of the Forest Products Laboratory acid-hydrolysis process, in which the wood is hydrolyzed with an alkaline medium which becomes slightly acid at the end of the cook, gives a similar molding powder with superior strength properties to those of the acid-hydrolyzed product. This material, when used with only 25 percent of phenolic resin, still lacks the rapid and more extensive flow of the ordinary phenol-formaldehyde molded products, which results from the greater content of phenolic resin. Although the addition of more resin improves the flow, it reduces the price advantage. It is this lack of flow that has held back the commercial use of hydrolyzed-wood plastics. In large objects with limited need for flow, hydrolyzed-wood plastics may, however, be used to advantage because of the lower cost. On the basis of the phenolic resin costing 20 cents a pound, wood flour costing 2 cents per pound, and hydrolyzed wood costing 4 cents a pound, the raw material for the hydrolyzed-wood plastic would cost 8 cents per pound, in contrast to 11 cents per pound for the present material.

Research is under way at the Forest Products Laboratory to put the lignin into a more plastic form so as to improve its flow characteristics and also avoid the embrittling effect on the cellulose caused by the hydrolytic methods that have been used to date.

The hydrolyzed-wood plastic requires pressures of 3,000 to 4,000 pounds per square inch at elevated temperatures for molding similar to the present molding powders. This necessitates expensive presses and molds. There is a crying need for molding compositions that can be cold formed in a simple hand press, perhaps followed by a simple baking. This problem, too, is being attacked at the Forest Products Laboratory. The chief difficulty to date has been that the simpler, cheaper compositions which are readily hand molded all exhibit considerable shrinkage on baking.

Unfortunately, none of the molding compositions show promise of utilizing very large quantities of wood waste. For example, if all of the present phenol-formaldehyde molded products were to be replaced by the hydrolyzed-wood plastics, three moderate-sized lumber mills could furnish all the raw material needed in the country. As board materials show promise of larger volume consumption, considerable attention has been focused at the Forest Products Laboratory in making such materials.

The hydrolyzed-wood molding powders are not suitable for making board materials with adequate strength properties, notably toughness. The strength properties can be greatly improved by having the cellulose reinforcing material present in longer-fibered form. This can be accomplished by using hardwood chips in place of sawdust and abrading the washed hydrolyzed chips while still wet to a pulp rather than grinding to a powder after drying. This pulp can be made into paper on a paper machine. After incorporating 10 to 15 percent of phenolic resin, these sheets can be pressed at elevated temperatures and a pressure of about 2,000 pounds per square inch

into a high-density board with quite good strength properties and water resistance. The board cannot be nailed but can be drilled. This, together with its high density and molding cost, do not make it attractive for general housing applications. It, however, should be suitable for electrical paneling and for such purposes as shower-bath walls.

More recently pulp boards have been made by the Forest Products Laboratory from the hydrolyzed chip fiber by forming thick pulp mats that are pressed wet under a pressure of 100 pounds per square inch or less without the addition of any phenolic resin. These boards have quite good properties comparable to those of untempered commercial hardboards. The boards which have a specific gravity of about 1.0 can be nailed. They can be made from softwoods as well as hardwoods, but the strength properties and water resistance of the softwood product are somewhat inferior.

Although these and other similar hardboards show promise for use as a sheathing material for houses and in other ways that wood is used, they are far from being synthetic lumber. Their use in housing will, undoubtedly, expand. Some new producers will undoubtedly succeed. If all who have contemplated production of these board materials actually go into production, however, a state of overproduction will be inevitable.

Destructive Distillation

Prior to the development and the industrialization of the present process for making synthetic wood alcohol, wood distillation was a profitable industry. Only a few plants have survived this development. During the war period, however, considerable interest in distillation has been revived, largely because of the increased demand for charcoal. No new extensive plants have been built but some charcoal manufacture without recovery of volatiles has been renewed. There is still, however, the possibility of reviving the wood-distillation industry by introducing new principles of distillation that will result in other than the conventional products. Such distillation principles can be applied to lignin residues from which it has been shown that valuable phenolic compounds can be obtained. The Forest Products Laboratory is again launching on a destructive-distillation research program after an inactive period of about 20 years, as it is felt that the introduction of new techniques may revive an old industry that under the old methods does not have a promising postwar outlook.

Hydrogenation of Wood

It has been shown from pioneer research at the Forest Products Laboratory that lignin dissolved in organic solvents or suspended in water can be made to react with hydrogen gas at elevated temperatures and pressures in the presence of various metallic catalysts. Among the products of the reaction are several brand new cyclic alcohols that had never been previously described in the literature. These show promise as plastic solvents, antiknock agents for motor fuel, and toxic agents. By varying the hydrogenation

conditions, phenolic compounds which may find use in plastics and complex neutral oils, together with a plastic-like residue, are obtained.

Wood waste or chips can also be hydrogenated in aqueous suspension to produce soluble lignin decomposition compounds and a cellulose pulp residue. This is a possible new pulping process that will be studied further by the Forest Products Laboratory. Under more severe hydrogenation conditions the cellulose can be converted to glycerine and sugars. In this case the entire wood is converted to liquid products.

All these findings are too new to predict their future application. Most of the data have been obtained in small bombs and in continuous hydrogenation equipment designed for other hydrogenation reactions. Continuous hydrogenation equipment is being built at the Forest Products Laboratory for continuing this work.

Modified Woods

The modification of wood by chemical treatments and by compression has excited a great deal of interest during the war period as a result of the publicity which the materials have received. These modified woods should not be thought of as improved forms of general utility lumber, as has often been inferred, but specialty materials for uses where their special properties are needed.

Impreg

Wood treated with phenolic-resin forming chemicals according to the Forest Products Laboratory method in which the chemicals enter and bond to the cell-wall structure, followed by drying and curing of the resin within the structure, is known as impreg. When resin is thus made an intimate part of the wood the tendency of the wood to swell and shrink is permanently reduced. Phenolic-resin forming systems have proven to be the most effective in dimensionally stabilizing wood. Reductions in the equilibrium swelling and shrinking to 30 percent of normal are possible with phenolic resins. Urea resins, which have been highly publicized of late for this purpose, reduce the equilibrium swelling by only half as much.

Stabilization of wood by a resin treatment differs from preservative and fire-retardant treatments in that it must be much more complete. The resin must be uniformly distributed throughout the entire cell-wall structure to be fully effective. For this reason the treating of lumber and the treating of freshly felled logs has not met with the success that some investigators have claimed. The Forest Products Laboratory has found that veneer of practically any species and many species of solid wood in lengths up to a foot or two can be adequately treated. Practically none of the woods can be properly treated in lumber lengths. Even if lumber could be adequately treated, the increase in cost would make the material prohibitively expensive for the majority of proposed uses. It is nevertheless

felt that the resin treatment of veneer for facing of plywood and for various specialties will find considerable use.

The face checking of plywood can be practically eliminated merely by facing normal plywood with phenolic-resin-treated faces.

The treatment also imparts to the panels considerable resistance against decay, termite, and marine-borer attack. A panel consisting of two resin-treated face plies with a single untreated core ply was inserted in the ground for 1 year in a field in Mississippi where termite action is severe. The termites tried the faces but found them not to their liking. Like good soldiers who have failed in a frontal attack, they tried a flank attack and, finding the core just what they wanted, proceeded to clean it out. Similar material that has had the edges protected with a preservative treatment and material with all the plies treated is, in some instances, sound after 5 years.

The resin treatment further cuts down the passage of water vapor through the panels to a marked extent, greatly increases the electrical resistance and the resistance to most chemicals with the exception of strong alkalies. Contrary to many of the publicity claims, resin treatment has a negligible effect in improving fire resistance. Fire-resistant salts, however, may be incorporated into the wood together with the treating resin and fixed in the structure by the treating resin to give quite good fire-retardant properties.

Only a few of the strength properties of wood are significantly increased by a resin treatment and the toughness is significantly decreased, which is contrary to much of the publicity on resin-treated wood. The only properties that are significantly increased are hardness, compressive strength, and abrasion resistance, and these are increased to a greater extent than the weight only at high resin contents.

Impreg was manufactured during the war only for military uses, one of which was for housings for electrical control equipment, in which the improved electrical properties are taken advantage of and another in an as yet unreleased use in which the improved abrasion resistance is utilized. Impreg shows the greatest promise for postwar use as resin-treated faces for ordinary plywood. Such panels might be used as house, trailer, and boxcar siding, flooring, and paneling. It still has to be proven, however, that the improved properties warrant the increased cost.

Compreg

Compreg is the name given by the Forest Products Laboratory to their stable form of resin-treated compressed wood. Its dimensional stability, resistance to organisms, chemicals, and flow of electricity are practically the same as for impreg. Most of the strength properties are increased about in proportion to the compression. It is tougher than impreg but not quite so tough as the original wood.

Due to the plasticizing action of the resin-forming chemicals on wood at temperatures used in hot pressing, the treated wood can be appreciably compressed under a pressure which scarcely compresses an untreated control. Because of this plasticizing action of the resin-forming chemicals on wood it is possible to make a combination of resin-treated compressed faces on an untreated uncompressed core in a single assembly and compression operation. It is felt that in this form compreg will find most of its postwar uses.

When compreg is compressed to a specific gravity of about 0.9 to 1.4, it assumes a glossy finish which persists throughout the structure. A cut surface can be sanded and buffed to a high degree of finish without the use of applied coatings. This is a feature of compreg which would make it desirable for use in furniture and flooring. Panels with a yellow-poplar compreg face, yellow-poplar impreg back and a Douglas-fir plywood core have been made for a flooring service test that is now under way in one of the Forest Products Laboratory offices.

Compreg, largely in the form of thick, highly compressed panels, has been manufactured during the war by seven companies for war use, chiefly in the manufacture of propellers. Compreg has also been used to some extent for various connector and bearing plates, aerial antenna masts, and tooling jigs. Solid compreg shows promise for postwar use in pulley and gear wheels, bearings, tooling jigs; shuttles, bobbins, and picker sticks for looms; high-strength electrical insulators; knife handles; and various decorative novelties. Compreg has better strength properties than fabric-reinforced plastics and it should be appreciably cheaper due to the fact that veneer is cheaper than fabric and about half as much resin is used in making compreg as is used in the fabric-reinforced plastics. Compreg may thus replace these plastics in a number of uses.

Staypak

Resin-treated wood in both the uncompressed and compressed forms is, unfortunately, more brittle than the original wood. To meet the demand for a tougher compressed product than compreg, a compressed wood containing no resin was developed by the Forest Products Laboratory. It will not lose its compression under swelling conditions as will ordinary compressed wood. This material, named staypak, is made by modifying the compressing conditions so as to cause the lignin cementing material between the cellulose fibers to flow sufficiently to eliminate the internal stresses. Staypak is not so water-resistant as compreg, but it is twice as tough and has higher tensile and flexural properties. The natural finish of staypak is almost as good as that of compreg. Under weathering conditions, however, it is definitely inferior to compreg. For outdoor use staypak should have a good synthetic resin varnish or paint finish. Staypak can be used in the same way as compreg where extremely high water resistance is not needed. It shows promise for use in propellers, tool handles, forming dies and connector plates where high impact strength is needed.

Staybwood

The cheapest and simplest method of imparting dimensional stability to wood thus far found is to heat the wood under conditions that just avoid charring. This can be done with a minimum loss in strength properties by the Forest Products Laboratory method of heating under molten metal for a few minutes. The wood becomes dark brown in color, loses about half of its original toughness, together with moderate losses in other strength properties. Equilibrium swelling and shrinking can be reduced to 60 percent of normal and an appreciable decay resistance is imparted to the wood by this treatment. Staybwood may find some use in places where dimensional stability and moderate decay resistance are more important than strength.

Conclusions

Although a great deal has been accomplished in developing means of chemically utilizing wood and in making modified woods, no universally successful process of utilizing the vast amount of inferior or waste wood has been developed. Individual operators, however, may be successful in using any of the processes discussed. Their success will largely depend upon making careful surveys of the source of wood supply, markets, and economical size of the prospective plant before venturing into any extensive operations.

Although the modified-wood field is primarily based on using high-quality wood chiefly in the form of veneer, there is the possibility of some manufacture based on the use of short dimension stock that is classed as waste because of size rather than quality. Compreg knife and other handles, knobs, and various decorative novelties can all be made to advantage from short lengths of solid wood rather than from veneer. The increased value of the product would make possible a more scrupulous selection of wood than would be possible for similar products made from untreated wood.

Further research on chemical utilization and modification of wood will undoubtedly expand the present possibilities of waste utilization, but the chemist needs the help of the forester in working out the problem of delivering the waste cheaply in large quantities to the processing plants.

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